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How Persistent Low Expected Returns Alter Optimal Life Cycle Saving, Investment, and Retirement Behavior

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How Persistent Low Expected Returns Alter Optimal Life Cycle Saving, Investment, and Retirement Behavior

Abstract

This paper explores how an environment of persistent low returns influences saving, investing, and retirement behaviors, as compared to what in the past had been thought of as more “normal” financial conditions. Our calibrated lifecycle dynamic model with realistic tax, minimum distribution, and Social Security benefit rules produces results that agree with observed saving, work, and claiming age behavior of U.S. households. In particular, our model generates a large peak at the earliest claiming age at 62, as in the data. Also in line with the evidence, our baseline results show a smaller second peak at the (system-defined) Full Retirement Age of 66. In the context of a zero return environment, we show that workers will optimally devote more of their savings to non-retirement accounts and less to 401(k) accounts, since the relative appeal of investing in taxable versus tax-qualified retirement accounts is lower in a low return setting. Finally, we show that people claim Social Security benefits later in a low interest rate environment.

Keywords

dynamic portfolio choice; 401(k) plan; saving; Social Security claiming age; retirement income; minimum distribution requirements; tax

Disciplines

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Comments

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How Persistent Low Returns Will Shape Saving and Retirement

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Chapter 8

How Persistent Low Expected Returns Alter Optimal Life Cycle Saving, Investment, and Retirement Behavior

Vanya Horneff, Raimond Maurer, and Olivia S. Mitchell

Low interest rates are now a reality not only in the United States but around the world, as recently noted by former Federal Reserve Chairman Ben Bernanke (2015). In the US, the government can borrow for a decade at a yield of only 2.3 percent, while in Switzerland, government bond yields are negative out to 50 years (Lewin 2016; Zeng 2017). Our chapter explores how this environment of persistent low returns is likely to influence saving, investing, and retirement behaviors, compared to what in the past were deemed more 'normal' financial conditions.

The persistence of low returns has implications for many aspects of the financial market. In the case of defined benefit (DB) pensions, a permanently low interest rate can render the DB plan underfunded, particularly when actual returns prove to be below those assumed when discounting future payouts. In the case of defined contribution (DC) plans, which are now the norm in the United States, the implications are more complex. In particular, persistent low returns can compel workers to save more and invest differently when allocating across stocks and bonds. Moreover, the low interest rate environment can also change retirement decisions, especially regarding how long to work and when to claim social security benefits.

This chapter builds on a number of studies using a life cycle framework to model and evaluate how individuals respond to a range of environmental shocks. The workhorse model of Cocco et al. (2005) and Gomes and Michaelides (2005) was extended by Love (2010) and Hubener et al. (2016), who showed how family shocks due to changes in marital status and children alter optimal consumption, insurance, asset allocation, and retirement patterns. In Horneff et al. (2015), we demonstrated how capital market surprises can influence saving and portfolio allocation patterns, and in Chai et al. (2011) we showed how flexible work patterns can help people hedge both earnings and capital market risk. In the present chapter, we evaluate how people might optimally respond to a *persistently* low return environment by adjusting their consumption, saving, investment, and retirement patterns compared to what used to be perceived as the 'normal' environment. Our chapter therefore builds on and extends the recent life cycle model developed by Horneff et al. (2016). In contrast to that study, we do not include annuity purchases but we do allow flexible work effort and endogenous claiming of social security benefits.[1]

In what follows, we develop and calibrate a life cycle model that embeds stock market and labor market uncertainty, as well as stochastic mortality. We also incorporate US tax rules and minimum distribution requirements for 401(k) plans, as well as real-world social security benefit formulas. We then show that our calibrated life cycle dynamic model produces realistic results that agree with observed saving, work, and claiming age patterns of US households. In particular, our model generates a large peak at the earliest benefit claiming age at 62, as in the data. Also in line with the evidence, our baseline results show a smaller second peak at the (system-defined) Full Retirement Age (FRA) of 66. In the context of a zero-return environment, we show that workers devote more of their savings to non-retirement accounts and less to 401(k) accounts since the relative appeal of investing into taxable versus tax-qualified retirement accounts is higher in a low return setting. Finally, we show that people claim social security benefits later in a low interest rate environment. A short discussion concludes.

The Consumer's Life Cycle Problem: Model and Calibration

In this section we build and calibrate a dynamic consumption and portfolio choice model for a utility-maximizing individual over the life cycle.

Preferences. We work in discrete time and assume that the individual's decision period starts at $t = 1$ (age of 25) and ends at $T = 76$ (age 100); accordingly, each period corresponds to one year. The household has an uncertain lifetime whereby the probability to survive from t until the next year $t + 1$ is denoted by p_t. Preferences in each period is represented by a Cobb Douglas function $u_t(C_t, l_t) = \frac{(C_t l_t^{\alpha})^{1-\rho}}{1-\rho}$ based on current consumption C_t and leisure time l_t normalized as a fraction of total available time. The parameter α measures leisure preferences, ρ denotes relative risk aversion and β is the time preferences factor. The recursive definition of the value function is given by:

$$J_t = \frac{(C_t l_t^{\alpha})^{1-\rho}}{1-\rho} + \beta E_t(p_t J_{t+1}), \tag{1}$$

with terminal utility $J_T = \frac{(C_T l_T^\alpha)^{1-\rho}}{1-\rho}$ and $l_t = 1$ after retirement. Following prior research in Horneff et al. (2016), the baseline calibration sets $\rho = 5$ and $\beta = 0.96$ for both males and females. The survival rates entering the value function are taken from the US Population Life Table (Arias 2010). We calibrate the leisure parameter α in such a way that our results match empirical claiming rates reported by the US Social Security Administration. This matching procedure produces leisure preference parameters of $\alpha = 0.9$ for males and $\alpha = 1.1$ for females.

Time budget, labor income, and social security retirement benefits. Our model allows for flexible work effort and retirement ages. The worker has the opportunity to allocate up to $(1 - l_t) = 0.6$ of his available time budget (assuming 100 waking hours per week and 52 weeks per year) to paid work. Depending on his work effort, the uncertain yearly pre-tax labor income is given by:

$$Y_{t+1} = (1 - l_t) \cdot w_t \cdot P_{t+1} \cdot U_{t+1} \tag{2}$$

Here w_t is a deterministic wage rate component, which depends on age, education, sex, and if the individual works overtime, full time, or part time. The variable $P_{t+1} = P_t \cdot N_{t+1}$ is the permanent component of wage rates with independent lognormal distributed shocks $N_t \sim LN(-0.5\sigma_P^2, \sigma_P^2)$ with a mean of one and volatility of σ_P^2. In addition $U_t \sim LN(-0.5\sigma_U^2, \sigma_U^2)$ is a transitory shock with volatility σ_U^2 and uncorrelated with N_t.

The wage rate calibration builds on Horneff et al. (2016), who estimated the deterministic component of the wage rate process w_t^i and the variances of the permanent and transitory wage shocks N_t^i and U_t^i using the 1975–2013 waves of the Panel Study of Income Dynamics.[2] These are estimated separately by sex and by educational level, where the latter groupings are less than High School, High School graduates, and at least some college (<HS; HS; Coll+).[3]

Between ages 62 and 70, the worker can retire from work and claim social security benefits, the latter of which depend on his average lifetime 35 best years of earnings. If the individual claims benefits before (after) the system-defined Normal Retirement Age of 66, then his lifelong social security benefits will be reduced (increased) according to pre-specified factors. If the individual works beyond age 62, we require that he devote at least a minimum effort of at least one hour per week; also, overtime work is excluded (i.e., $0.01 \leq (1 - l_t) \leq 0.4$).

Wealth dynamics during the work life. During working life, the individual has the opportunity to use current cash on hand for consumption and investments. Some portion A_t of the worker's pre-tax salary Y_t (up to a limit of \$18,000 per year) can be invested into a tax-qualified 401(k)-retirement plan of the EET type.[4] That is, contributions into the account and investment earnings on account assets are tax-exempt, (E), while withdrawals are taxed (T). In addition, a worker can invest outside his retirement plan in risky stocks S_t and riskless bonds B_t. As such, his cash on hand X_t in each year is given by

$$X_t = C_t + S_t + B_t + A_t \tag{3}$$

where the usual constraints $C_t, A_t, S_t, B_t \geq 0$ apply. One year later, his cash on hand is given by the value of stocks (bonds) having earned an uncertain (riskless) gross return of R_{t+1} (R_f), plus income from work (after housing expenses h_t), plus withdrawals (W_t) from the 401(k) plan, minus any federal/ state/city taxes and social security Tax_{t+1} contributions:

$$X_{t+1} = S_t R_{t+1} + B_t R_f + Y_{t+1}(1 - h_t) + W_t - Tax_{t+1} \tag{4}$$

We model housing costs h_t as in Love (2010). Our 'baseline' financial market parameterizations assume a risk-free interest rate of 1 percent, and an equity risk premium of 4 percent with a return volatility of 18 percent. In simulations below of the low-yield environment, we vary these assumptions.

During his working life, the individual pays taxes (Tax_{t+1}), which reduce his cash on hand available for consumption and investments.[5] These include the labor income tax at a rate of 11.65 percent (the sum of 1.45 percent Medicare, 4 percent city and state tax and 6.2 percent social security tax). Under the US progressive tax system, the individual must pay taxes on labor income as well as on withdrawals from tax-qualified retirement plans (including a 10 percent penalty tax for withdrawals before age 60), and on returns on stocks and bonds held outside the tax-qualified retirement account. If his cash on hand falls below $X_{t+1} \leq 5,950$ p.a. (an amount also exempt from income taxes), he is supported by the state, so he has a minimum wealth level of $5,950$ for the next year.

Prior to the endogenous retirement age $t = K$, the assets in his tax-qualified retirement plan are invested in bonds earning a risk-free gross (pre-tax) return of R_f and risky stocks with an uncertain gross return of R_t. The total value ($F_{t+1}^{401(k)}$) of the 401(k) assets at time $t + 1$, usually held in a 401(account), is determined by the previous period's value minus any withdrawals ($W_t \leq F_t^{401(k)}$), plus additional contributions (A_t), and returns from stocks and bonds:

$$F_{t+1}^{401(k)} = \omega_t^s \left(F_t^{401(k)} - \mathrm{W_t} + A_t\right)\mathrm{R_{t+1}} + (1 - \omega_t^s)\left(F_t^{401(k)} - \mathrm{W_t} + A_t\right)R_f, \mathit{for}\ t < K \tag{5}$$

We posit that his DC plan assets are held in a Target Date Fund with stock exposure declining with age following the common rule $\omega_t^s = (100 - Age)/100$.[6] This is a Qualified Default Investment Alternative (QDIA) as per Department of Labor regulations (US DOL 2006).

Wealth dynamics during retirement. The worker can retire and claim social security benefits between age 62 and 70. After retirement at the endogenous age K, the individual has the opportunity to save outside the tax-qualified retirement plan in stocks and bonds:

$$X_t = C_t + S_t + B_t \tag{6}$$

His cash on hand for the next period evolves as follows:

$$X_{t+1} = S_t R_{t+1} + B_t R_f + Y_{t+1}(1 - h_t) + W_t - Tax_{t+1}. \tag{7}$$

Old age retirement benefits provided by Social Security are determined by the worker's Primary Insurance Amount (PIA), which depends on his 35 best years of earnings.[7] Social Security payments (Y_{t+1}) in retirement $(t \geq K)$ are given by:

$$Y_{t+1} = PIA_K \cdot \lambda_K \cdot \varepsilon_{t+1.} \tag{8}$$

Here, λ_K is the adjustment factor for claiming before or after the normal retirement age, which is equal to age 66.[8] The variable ε_t is a transitory shock $\varepsilon_t \sim \mathrm{LN}(-0.5\sigma_\varepsilon^2, \sigma_\varepsilon^2)$, which reflects out-of-pocket medical and other expenditure shocks in retirement as in Love (2010). During retirement, benefits payments from Social Security are partially taxed[9] by the individual federal income tax rate as well as the 1.45 percent Medicare and 4 percent city and state taxes.

We model the 401(k) plan payouts as follows:

$$F_{t+1}^{401(k)} = \omega_t^s \left(F_t^{401(k)} - \mathrm{W_t}\right)\mathrm{R_{t+1}} + (1 - \omega_t^s)\left(F_t^{401(k)} - \mathrm{W_t}\right)R_f, for\ t < K \tag{9}$$

Under US law, plan participants must take retirement account payouts from age 70 onwards, according to the Required Minimum Distribution rules (m) specified by the Internal Revenue Service (2012). Accordingly, withdrawals from the retirement account must take into account the following constraints: $F_t^{401(k)} m \leq W_t < F_t^{401(k)}$.

Baseline Results in a 'Normal' Interest Rate Environment

Next we evaluate, in a 'normal' interest rate world, how people would optimally choose their consumption, work effort, the claiming age for social security benefits, investments in as well as withdrawals from tax-qualified 401(k) plans, and investments in stocks and bonds. We posit that households maximize the value function (1) under budget restrictions. This optimization problem cannot be solved analytically, so it requires a numerical procedure using dynamic stochastic programming. To generate optimal policy functions, in each period t we discretize the space in four dimensions $30(X)\times 20\,(F^{401(k)})\times 8(P)\times 9(K)$, with X being cash on hand, $F^{401(k)}$ assets held in the 401(k) retirement plan, P permanent income, and K the claiming age. Next, we simulate 100,000 independent life cycles based on optimal feedback controls for each of the six population subgroups of interest (male/female with <HS, HS, and Coll+). We then aggregate the subgroups to obtain national mean values using weights from the National Center on Education Statistics (2012). Specifically, the weights are 50.7 percent female (and 62 percent with Coll+, 30 percent with HS, and 8 percent with <HS), and 49.3 percent male (and 60 percent with Coll+, 30 percent HS and 10 percent <HS).

Figure 8.1 reports results for our baseline calibration assuming a risk-free interest rate of 1 percent, and an expected return on stocks of 5 percent with a volatility of 18 percent. The life cycle graphs appear in the upper panels, while social security benefit claiming behavior appears in the lower panels. Moreover, results for men appear on the left, and for women on the right.

Panels A and B of Figure 8.1 demonstrate that, during working life, labor income substantially exceeds consumption. This is partly due to the fact that we show pre-tax income, so after income taxes, net labor income tracks consumption more closely. During the worker's first decade in the job market, he saves only a small amount due to the fact that he is liquidity-constrained when young. (The worker also cannot increase consumption by borrowing against future labor income). From age 35 onward, savings rise, especially in the 401(k) plan retirement plan to peak around age 59. Thereafter, he systematically draws down assets from the plan, since after age 59.5, he need no longer pay the 10 percent penalty tax for early withdrawals. In retirement, between age 62 and 70, his social security income falls below average consumption, with the difference financed by retirement plan withdrawals.

For women, though their labor income is lower than for males, they still accumulate almost the same amount of retirement plan assets. This can be explained by the fact that the average life expectancy for women is substantially higher than for men, so women must save more to maintain desired consumption levels over a longer period. For example, at age 25 (the starting point of our life cycle model), the life expectancy of females is age 81, or about 4.5 years more than for males. Both women's and men's consumption drops slightly during the retirement period, which is in line with both empirical evidence and theoretical life cycle literature (Battistin et al. 2009; Chai et al. 2011). This can be explained by the sharp increase in leisure time after people claim social security benefits.[10]

Panels C and D of Figure 8.1 reveal that the social security claiming patterns generated by our model align closely with empirical claiming

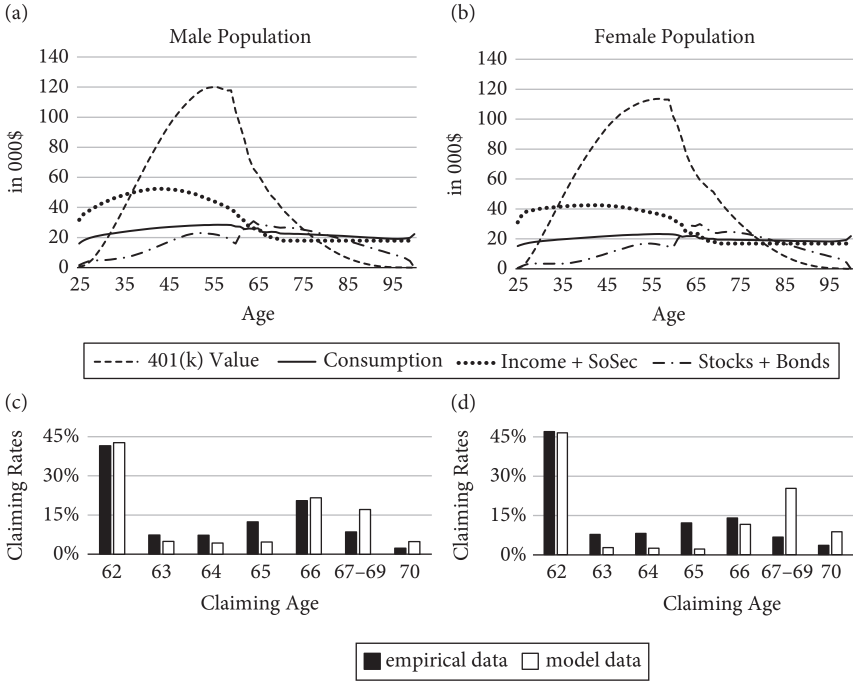

Figure 8.1. Life cycle behavior and social security claiming patterns for males and females

Note: The top two panels show expected life cycle patterns for males and females (consumption, income, assets in 401(k) tax-qualified plans, and bonds/stocks). The lower two panels present claiming rates generated by our life cycle models versus empirical claiming rates as reported by the US Social Security Administration for the year 2014. Expected values are calculated from 100,000 simulated lifecycles based on optimal feedback controls. Results for the entire female (male) population are computed using income profile for three education levels: 62% +Coll; 30% HS; 8% <HS (60% +Coll; 30% HS; 10%<HS). Parameters used for the baseline calibration are as follows: risk aversion $\rho = 5$; time preference $\beta = 0.96$; leisure preference $\alpha = 0.9$ (female) $\alpha = 1.1$ (male); endogenous retirement age 62–70. Social Security benefits are based on average permanent income and the bend points in place in 2013; minimum required withdrawals from 401(k) plans are based on life expectancy using the IRS-Uniform Lifetime Table in 2013; tax rules for 401(k) plans are as described in Horneff et al. (2015). The risk premium for stocks returns is 4% and return volatility 18%; the risk-free rate in the baseline case is 1%.

Source: Authors' calculations.

rates reported by the US Social Security Administration.[11] That is, our model generates a large peak at the earliest claiming age at 62, whereas in the data, about 45 percent of workers claim their benefits at this point. Additionally, and also in line with the evidence, our baseline results show a smaller second peak at the (system-defined) FRA of 66; here about

15 percent of workers claim benefits for the first time. Overall, the results of our baseline calibration confirm that our model produces realistic results that agree with observed work, saving, and claiming age behavior of US households.

Understanding the Impact of Interest Rates

Having provided the baseline 'normal' environment results, we next evaluate the changes in a different interest rate environment. To this end we examine two experiments. First, we reduce the (real) risk-free interest from 1 percent to 0 percent, and second, we increase the real interest rate to 2 percent. (In both cases we keep the equity risk premium at 4 percent). Table 8.1 reports results for men and women, separately.

In Table 8.1, we report the rates at which people claim their social security benefits by age, as well as the overall claiming age. One key finding is that the lower the risk-free interest rate, the higher the claiming age. In other words, when the long-term interest rate falls to zero, women claim about 0.4 years later, and men almost a full year later. Another point to note is that claiming at the earliest possible age of 62 declines quite notably, more so for men but also for women. We explain this by noting that, when expected returns are high, the worker can claim early social security benefits without needing to withdraw as much from his retirement assets, which continue to earn higher returns for a while longer. But when the real interest rate is low, a worker can delay claiming social security in exchange for higher lifelong benefits, and the cost of taking more from his retirement count to support consumption is lower. This is in line with Shoven and Slavov (2014) who argued that, by delaying claiming, people can maximize the actuarial net present value of their lifetime social security benefits in times of low returns.

TABLE 8.1 Social security claiming ages for females and males

	Claiming rates (%) by age									Average Claiming Age
	62	63	64	65	66	67	68	69	70	
Panel A: Female										
0% Interest Rate	46.1	2.1	2.2	3.1	7.2	5.5	9.8	10.7	13.3	65.1
1% Interest Rate	46.6	2.8	2.6	2.3	11.6	7.4	10.0	7.9	8.8	64.8
2% Interest Rate	47.6	2.5	2.4	2.4	13.1	9.9	9.6	5.4	6.9	64.7
Panel B: Male										
0% Interest Rate	39.9	3.5	4.7	4.6	16.3	13.1	7.2	5.2	5.5	64.8
1% Interest Rate	42.7	4.9	4.3	4.7	21.6	11.3	3.4	2.4	4.8	64.5
2% Interest Rate	49.6	5.6	4.5	6.2	24.7	4.0	1.5	1.4	2.6	63.9

By contrast, when returns are higher, the net present value of benefits is maximized by claiming early. Evidence from Shoven and Slavov (2012) and Cahill et al. (2015) also suggests that low (high) interest rates result in later (earlier) claiming ages. Accordingly, our results are in line with empirical evidence.

Table 8.2 shows how wealth accumulation changes under the two interest rate regimes, both inside and outside the 401(k) plan. In the low return environment, workers build up less wealth in their retirement plans. For instance, when the safe yield is 0 percent, middle aged women (aged 55–64) optimally accumulate an average of about $88,200 in their 401(k) plans, while in the 2 percent yield scenario, they average one-third more, or $117,700, at the same point in their life cycle. Middle-aged men accumulate $83,200 in the zero-rate environment, and 45 percent more ($120,600) in the 2 percent interest rate scenario. Interestingly, the opposite pattern applies to assets held outside the tax-qualified retirement plans. That is, women age 45–54 hold $16,600 in liquid stocks and bonds when the interest rate is zero, but only $9,800 in the 2 percent interest rate scenario. The same effect also applies to males.

The divergent impact of low versus high interest rates on asset holdings inside versus outside tax-qualified retirement plans can be explained as follows. When the interest rate is low, people work fewer hours per week

TABLE 8.2 Life cycle asset accumulation patterns for females and males

	Female			Male		
	0% Interest Rate	1% Interest Rate	2% Interest Rate	0% Interest Rate	1% Interest Rate	2% Interest Rate
Panel A: 401(k) assets in $000						
Age 25–34	16.8	18.1	21.1	9.9	13.6	14.9
Age 35–44	57.9	70.0	80.2	48.6	65.0	70.3
Age 45–54	92.4	105.0	124.4	91.4	109.2	122.7
Age 55–64	88.2	99.5	117.7	83.2	101.6	120.6
Age 65–74	33.5	48.4	64.4	27.4	43.6	63.1
Age 75–84	10.8	19.5	30.8	8.5	16.0	26.4
Age 85–94	1.6	4.0	7.9	1.2	2.7	5.8
Panel B: Non-qualified assets in $000						
Age 25–34	2.7	3.0	2.6	6.4	4.5	4.3
Age 35–44	11.1	5.8	4.9	18.3	10.8	10.8
Age 45–54	16.6	14.0	9.8	25.6	21.1	18.6
Age 55–64	16.5	19.3	16.0	24.7	22.6	18.3
Age 65–74	25.3	25.9	25.3	28.4	27.2	25.3
Age 75–84	19.7	21.2	21.8	21.1	22.2	23.3
Age 85–94	11.5	13.0	14.1	12.5	13.9	14.3

early in life, compared to workers in the higher interest environment. For example, women work two hours per week less between ages 25 and 60 than they do in the 2 percent interest rate scenario.[12] The reason is that, in the higher return scenario, it is more attractive to build up savings early in life as these can grow at the higher rate. More work effort then generates higher labor income, and because of the progressive tax system, this results in larger allocations to the tax-exempt retirement accounts. In addition, returns earned on assets held inside the 401(k) plan are tax-free. This second advantage is, of course, smaller in a zero-return environment. Accordingly, when interest rates are low (high), workers devote more (less) of their savings to non-retirement accounts.

Conclusions

Financial writers have noted with concern that the long-term impact of very low interest rates has been to drive some investors to 'hunt for yield,' taking on riskier investments (Bryan 2016). Yet little academic research has focused on how persistent low returns would optimally shape workers' and retirees' decision making regarding accumulation and retirement patterns. Our life cycle model integrates realistic tax, social security, and minimum distribution rules, as well as uncertain income, stock returns, and mortality. The baseline calibration generates a large peak at the earliest claiming age at 62, in line with the evidence. Additionally, baseline results produce a smaller second peak at the (system-defined) FRA of 66. Overall, the results of the baseline calibration confirm that our model produces realistic results that agree with observed work, saving, and claiming age behavior of American households.

The results of alternative interest rate regimes are also quite informative. One sensible result is that people are predicted to save less during periods of low returns. Second, people finance consumption relatively early in retirement by drawing down their 401(k) assets sooner. Third, low rates also change *where* people save. During low-return periods, workers save less in tax-qualified accounts and more outside tax-qualified plans, until retirement. The reason is that the tax advantages of saving in 401(k) plans are relatively less attractive, inasmuch as the gain from saving in pre-tax plans is lower, and because the return on assets in the retirement account are lower in a low-return environment. And fourth, we find that low interest rates drive workers to claim social security benefits later, so they can take advantage of the relatively high payoff to deferring retirement under current rules. In this way, we confirm that tax and social security claiming rules have a powerful effect on how households are able to adjust to financial market fluctuations.

Notes

1. We also provide a theoretical backing for the empirical claiming age patterns identified by Shoven and Slavov (2012, 2014).
2. Dollar values are given in 2013 terms.
3. Details are given in Horneff et al. (2016).
4. This approach to retirement benefit taxation is therefore similar to how regular DB and DC plan payments are handled under US tax law. We abstract here from Roth 401(k)s.
5. For details, see Horneff et al. (2016).
6. This was suggested by Malkiel (1996), for instance.
7. The benefit formula is a piece-wise linear function of the Average Indexed Monthly Earnings providing (as of 2013) a replacement rate of 90 percent up to a first bend point ($791), 32 percent between the first and the second bend point ($4768), and 15 percent above that. See US SSA (2017).
8. The factors we use are 0.75 (claiming age 62), 0.8 (claiming age 63), 0.867 (claiming age 64), 0.933 (claiming age 65), 1.00 (claiming age 66), 1.08 (claiming age 67), 1.16 (claiming age 68), 1.24 (claiming age 69), and 1.32 (claiming age 70). See US SSA (2017).
9. For tax rules for social security see US Social Security Administration (2017). Based on the combined income up to 85 percent of social security can be taxed for households with high income additional to social security benefits. Yet because of quite generous exemptions, most households receive their social security benefits tax-free (see Horneff et al. 2016).
10. This pattern conforms to evidence on expenditure drops after retirement found by Aguiar and Hurst (2005).
11. For instance, see the US Social Security Administration (2015), Table 6.B5. We adjust their data to omit disability conversions at age 65 and scale the other age brackets so they sum to 100 percent.
12. These numbers are not reported in Tables 8.1 and 8.2; computations available on request.

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